THE GENETIC CLASSIFICATION OF GEOLOGICAL PHENOMENA.

In the consideration of every branch of natural knowledge, one of the first phases to receive attention is some ready means of comparing the various phenomena presented. Gradually there grows up some systemization of the facts and principles, that afterwards reflects the particular stage that the branch at that time attained. This orderly arrangement is the initial step in raising the branch to the dignity of a science.

Scientific advancement may be measured by the degree of taxonomic completeness shown, and by the character of the criteria regarded as critical. As progress is made a rapid evolution in the fundamental plan of grouping the facts takes place. In the beginning, a classification, crude though it may be, is outlined from those superficial features that, at first glance, are the most striking. This is, at a later stage, modified to one in which similarity of common characters, irrespective of natural relations, is taken into account. A vastly more advanced conception is classification based upon affinity, in which for similarity of features is substituted similarity of plan. The final stage is one in which origin, or causal relationship, is the governing principle. This is genetic classification.

At the present time the science of geology is just entering upon the stage last mentioned. As yet, no complete genetic scheme has been proposed. However, various attempts have been made to emphasize the principle of genetic association. All of these efforts appear to be too closely wrapped up in the older conceptions to show very much real advancement over them. They plainly indicate that the time is now ripe to seriously plan for a purely genetic arrangement of geological phenomena.

The older text-books on geology treat of all things geological

from the standpoint of the finished products. The idea that the latter are the visible expressions of many and constantly changing agencies has received only indirect or secondary practical consideration. As a result the production of many, if not most, geological features are loosely, or in a very vague way, ascribed to causes that are very complex. That is, instead of being single and simple the ascribed agencies are in reality a combination of several very distinct causes. For example, rock weathering is usually spoken of as if it were a single process in operation; whereas it involves the action of at least three distinct forces, one of which is strictly physical and the other two chemical, that are called into play separately or in conjunction.

So far as concerns the standpoint of treatment, the newer text-books on geological science are not much of an improvement over the older ones. The antiquated plans of making the products all important and of not distinguishing between processes still thoroughly permeate them. In some cases a little more space than formerly is devoted to "dynamical" geology, and a little less stress is placed upon the so-called historical section. Otherwise, there is relatively small difference between the geological manuals of today, and those of a quarter or a half century ago.

At this time it is not quite clear just what are the real reasons for this lagging of the manuals so far behind the science itself. Not the least important factor probably is that, as a rule, the makers of popular text-books are not in a broad way creative or productive investigators. The advance movement in geology began nearly a score of years ago, and today it is quite generally appreciated by all active workers, who face the subject in nature.

While it was only natural that geology should finally come to be placed upon a strictly genetic, or philosophic, basis, it was due primarily to the modern geographic school that the first strong impulses in this direction were given. The geographers, however, have not developed their side of the subject in as purely a genetic manner as they would have us believe, or as their opportunities permit. They certainly began in the right way, but in

the multitude of new conceptions and the maze of geographic forms that were presented, the analysis of the simple processes that were continually at work was largely overlooked.

So far as I am able to see, Gilbert appears to be the only one who has yet struck the right chord in the attempt to classify, by the processes, geological phenomena. As long ago as 1884 this writer proposed a "Plan for a Subject Bibliography of North American Geology," in which the geological agencies, instead of products are given primary consideration. How far the scheme would have been developed had it been allowed to go on cannot now be inferred. Since that time nothing further has been done in regard to this matter. The arrangement, presenting partly the common subdivisions of the subject of geology as given in our text-books, indicates that the author did not have in mind a classification that can be regarded as strictly genetic.

A few years later McGee suggested "a purely genetic taxonomy of geology, designed to include geography." This plan is particularly instructive as illustrating another phase of the subject. A critical examination of the scheme clearly shows that it is not really genetic except in name. Each product is made to have a constructive and a destructive phase. This plan has been, it may be here mentioned, seized with avidity by the more progresssive geographers. Its method is particularly attractive when applied to topographic forms, especially since it has been fully recognized that they all have "life histories." It is manifest, however, from the whole treatment of the theme that this plan has for its actual foundation the product and not the process. Stages of construction and of destruction must necessarily center around the feature and not the agency producing it. The essential characteristic of this scheme is the twofold nature of the production of every geographic form. When it is remembered that in the old geology the product is the all important factor, and in the new the process, it is at once seen that the dual plan is based entirely upon the old conception, and that the truly genetic principle is lost.

The plans of classification by genesis that have been formu-

lated by the geographers have to be made much more comprehensive than they now are, before they can accomplish their intended service. To begin with, an adequate scheme should be based directly upon geological agencies. Topographic features are largely only the outward expressions of the internal arrangement of the earth. The two groups of characters should be paralleled. One represents form — the physiognomy; the other structure — or anatomy. Yet some geographic features have no measurable equivalent in structure; and many structures do not give rise directly to distinctive forms of surface relief.

In a strictly genetic arrangement, where the processes and not the products are made the central theme, the continual operation of two antagonistic forces does not really exist. Constructive and destructive agencies can be recognized only when the phenomena are made the basis of the scheme. Processes are merely operative. If coupled with the products at all, in classification, all must be regarded as formative or constructive. The product's destruction, its loss of identity, is wholly immaterial. The action of agencies is merely to produce constant change.

A truly genetic scheme for the classification of natural phe nomena thus always has prominently presented its underlying principle of cause and effect. All products must find accurate expression in terms of the agencies. Only then are the broader distinctions in geological classification rendered possible. The various taxonomic groups are made separable only when it is recognizable how, or in what manner, the component parts of the materials dealt with are influenced. Under one set of agencies and conditions a rock-mass is affected in one way, and the component units act altogether differently from what they do under another set of agencies. The primary groupings of the geological processes must be based, therefore, upon the manner in which these agencies affect the rock materials.

When rocks, or the materials with which geology has to deal, and through the medium of which geological phenomena take definite form, are carefully considered with reference to

their behavior under different physical conditions, it is found that, broadly speaking, they are acted upon in four very distinct ways: (1) In a most comprehensive manner all the rocks of the globe act as a unit, and are affected as such by only the cosmical forces. They are then considered in their astral relations. (2) Again, physical forces may affect rocks as great bodies, masses or formations. This may be regarded as their corporeal aspect. (3) Rocks may also be influenced only as particles. They are then treated of in their molar relations. (4) Finally, rocks are changed by the motions of their molecules and atoms. The molecular agencies, as understood in this connection, are those commonly termed physical (in its most limited sense) and chemical. Since, for geological purposes, it is hardly necessary to make any distinction between the two processes of this class, both are called molecular.

Each of the main groups, or kinds of geological processes, has its several minor categories, and each of these its particular phases. Activity of the subordinate agencies as comprehended under the latter give rise to the various classes of geological structure and geographic form.

While a complete arrangement of all geological phenomena, according to the plan suggested, would necessarily require a critical inquiry into the whole subject of geology, some of the principal features of such a genetic scheme may be indicated by the accompanying outline.

From this arrangement may be readily inferred many of the shortcomings of our existing systems. Two points are also prominently brought out. One is the frequent origin of very similar products through the action of diverse processes. The other is the complicated nature of most of the agencies that we commonly regard as simple. The absolute necessity is thus shown for a new series of brief, self-explanatory terms that will enable us to express with exactness the various processes according to the modern view or modified conceptions.

In enumerating some of the chief processes affecting the rocks a number of familiar terms do not appear. Among these

CLASSIFICATION OF GEOLOGICAL PHENOMENA BY GENESIS.

Processes (Geodynamy)			Structures (Geotectonics)	Forms (Geography)
Kind	*Category*	*Phase*		
Astral (*as a unit*)	Refrigeration		Rock	Envelopes
	Revolution	Climatic		
	Rotation	Eolic Hydric Lithic		Trade winds Ocean currents Geosphere
	Gravitation	Depressive Repulsive	Epeiroclines	Continents, oceans Tides
Copo-real (*as masses*)	Diastrophism (Solid)	Plicative Fractural Displacive Fissile Fluent Comminutive	Flexures Joints Faults, thrusts Cleavage, fissility Schistosity Brecciation	Mountain ranges, great lakes, and seas Salients Fault scarps
	Vulcanism (Liquid)	Intrusive Effusive Explosive	Dikes, veins, silts, necks, laccolites, basics, etc. Lave sheets Ash beds	Ridges (some), peaks, domes, etc. Mesas, lava fields Cones, craters
Molar [Physical] (*as particles*)	Seismism			
	Cementation	Compressive		
	Disintegration	Frigidic Caloric Biotic		Regolith, talus slopes
	Gradation	Eolic Glacic Hydric	Stratification	Dunes, sand ridges, etc. Moraines, drumlins, kames, drift-plains, basins, some lakes Coastal plains, peneplains, flood plains, deltas, valleys, drainage systems, etc.
	Automotion	Vital Anthropic		Coral reefs, shell-banks, etc. Mounds, etc.
Molecular, or chemical. (*As molecules and atoms*)	Decomposition		Fissures (some)	Sinks, caverns, etc.
	Induration			Crags, reefs, water falls (some)
	Metamorphism	Paramorphic Metasomatic		
	Mineralization		Mineral veins (some)	
	Precipitation			

may be mentioned, for examples, weathering, erosion, deformation, transportation, and deposition. These are names that, as technical terms, do not now mean very much. While they are commonly used, and perform useful functions in certain cases, they really indicate an imperfect state of knowledge of the subject, or rather remissness in careful discrimination. All are compound processes, and involve the simultaneous action of several distinct agencies. Weathering includes, among other changes, the mechanical breaking down of rock-masses through the effects of heat and cold, the action of life or the application of pressure (disintegration); it involves the chemical alteration of some of the essential constituents, by which the identity of the rock-mass is lost (decomposition); and it also embraces, in its earlier stages, chemical change in which traces of the identity of the original rock are retained, but in which there has been some metasomatic replacement.

In the same way most of the other terms applied to "processes" are found to be ill-defined. Even metamorphism, which is, in the present connection, used in its limited petrographic sense, is a loose title. Usually it carries with it the idea of rock induration. Its complexity is hinted at by the use of such compounds as "contact" metamorphism and "regional" metamorphism. It actually embraces both metasomatic and paramorphic alteration, and sometimes also mineralization and cementation. Certain diastatic and vulcanic influences also profoundly affect its exact expression.

To one trained in some other than geological science, the most striking feature of the latter is a certain vagueness that seems to pervade the entire field. This is also the main difficulty that every beginner has to overcome. While after a time this trouble ceases to impress itself on the geologist himself it is nevertheless glaringly apparent in his conversation and especially in his writings. The outcome of closer attention to the only natural scheme of classification, the genetic one, is clearer discrimination of facts, greater precision of statement, and vastly better comprehension of the whole subject.

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